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Review Article

Illuminating the landscape of mathematical resilience: A systematic review

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This systematic review examines 31 articles published from 2000 to 2021, comprehensively addressing mathematical resilience. These articles originate from English-language journals indexed in Google Scholar, Web of Science, ERIC, and Scopus databases. The analysis considered specific aspects including years, countries, research methods, designs, sample characteristics, data collection instruments, analysis techniques, findings, and recommendations. The majority of studies were conducted in 2021, mainly in Indonesia and the United Kingdom, with a focus on high school students. Qualitative approaches predominated, particularly qualitative descriptive research, along with quantitative approaches featuring semi-experimental designs and correlational studies. Quantitative studies commonly employed mean and frequency tables, while surveys and interviews were frequently utilized data collection tools. These investigations revealed diverse dimensions of mathematical resilience, spanning cognitive, affective, pedagogical, demographic, and social domains. The studies offer valuable recommendations for educators, researchers, teacher education programs, learning environments, students, school administration, psychological counsellors, parents, and society at large.

Keywords: Mathematical resilience; Mathematics teaching; Systematic review; Affective components; Attitudes; Behaviours

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1. Introduction

Mathematics is recognized as the universal language of all disciplines (Parker Waller & Flood, 2016) and plays a crucial role in comprehending intricate concepts, solving problems, and conducting critical assessments. Nevertheless, mathematics is challenging for pupils in middle and high school (Lee & Johnston-Wilder, 2017). The challenge at hand could be intensified by the educational system's tendency to cultivate the notion that certain individuals possess inherent mathematical aptitude, thereby impeding the learning process even during later stages of life. Students may inadvertently omit a step when attempting to adhere to the prescribed procedures in mathematics, leading to an erroneous outcome. Repetitions of this procedure may engender the notion that their efforts are unproductive, thus causing the pupil to exhibit diminished effort in subsequent attempts (Lee & Johnston-Wilder, 2017). These stressful circumstances can induce a state of learned helplessness, leading to an increase in anxiety, immobility, and fear (Seligman,

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2018). These emotional responses might adversely affect student's learning performance (Skaalvik, 2018; Sorvo et al., 2019). This situation is widely acknowledged as an inherent outcome of anxiety (Yenilmez & Özbey, 2006). This anxiety, if left unchecked, can grow like a snowball, and become impossible to manage.

Given the related phenomena, understanding how mathematics anxiety influences student achievement (Jamieson et al., 2021) and how this anxiety is experienced becomes essential. Johnston-Wilder and Lee (2010) proposed the notion of "mathematical resilience" (MR) as a potential solution for this problem, delineating it as the capacity to exhibit positive reactions when confronted with difficulties. The structure of MR allows students to manage and protect against unhelpful emotions that may arise when learning mathematics becomes challenging. The idea behind this is to provide pupils with strategies for dealing with challenging mathematics situations and minimizing stress. Therefore, it is essential for teachers to develop strategies in this area and strengthen students' abilities in managing mathematics. A focus on these areas in educational policies is imperative, and there is a need for scientific studies to increase students' MR.

2. Theoretical Framework

A conceptual framework for MR was undertaken by Johnston-Wilder and Lee (2010). This framework emphasizes resilience as a global measure against mathematical difficulties. Initial theoretical studies suggest that the four primary factors of MR are belief in enhancing brain capacity, understanding the personal value of mathematics, grasping mathematical working strategies, and awareness of support from various sources (peers, adults, the Internet, etc.) (Lee & Johnston-Wilder, 2014). However, subsequent studies have focused more on four distinct factors: value, struggle, development, and resilience (Johnston-Wilder et al., 2013). These factors are key elements in augmenting students' abilities in MR during the mathematics learning process. The concept of MR is rooted in the framework of social constructivism, which highlights the potential of individuals to achieve based on their skills, but also acknowledges the influence of social environment and language (Vygotsky, 1978, cited in Lee & Johnston-Wilder, 2017). Within this framework, Lee and Ward-Penny (2022) provided a definition for MR, which they describe as an attribute marked by the ability to achieve successful outcomes despite difficult mathematical tasks, linked with a confident, persistent, and questioning disposition toward the subject. Morkoyunlu and Ayhanöz (2021) concurred with this definition, considering MR as expressing "a confident, persistent, and eager approach to mathematics for debating, reflecting, and investigating." It should be noted that MR possesses a strategic structure that empowers students to overcome emotional barriers. This approach provides students with a positive framework to cope with emotional obstacles (Johnston-Wilder & Lee, 2010).

Thornton et al. (2012) examined the core components of MR, which can be categorized into five primary domains: learning from mistakes, analyzing problem-solving processes, the development or reestablishment of skills, the recognition of knowledge gaps and the formulation of logical inquiries, and the motivation to seek the significance of learning. In addition, other researchers have indicated that MR includes belief in the value of mathematics, the desire to persist/fight, belief in growth associated with self-efficacy, and the ability to develop positive responses to adversities that may be encountered in the mathematics learning process (Lee & Johnston-Wilder, 2013; Hutauruk & Priatna, 2017).

According to Hutauruk and Naibaho (2020), MR can be described as the ability to exhibit resilience and flexibility while studying and mastering mathematics. Moreover, they compiled nine essential indicators to help students develop MR. The indicators encompass understanding mathematical proficiency, self-confidence, personal limitations, potential for failure, interdisciplinary application of mathematical knowledge, capacity to overcome challenges, future relevance of mathematics, and possession of essential knowledge. According to these indicators, a student with MR has social competence and independence (Goodall & Johnston-Wilder, 2015), perseverance in problem-solving and proficiency in strategic thinking ability (Peatfield, 2015), recognition of the significance of mathematics and self-confidence (Hutauruk & Priatna, 2017), and the ability to discuss and form mathematical ideas (Ariyanto et al., 2017). Other researchers such as Duah (2017) have pointed out that the notion of MR has transcended its status as a popular buzzword, garnering significant attention in numerous initiatives and research endeavours. The aforementioned theoretical framework offers substantial guidance in surmounting mathematical obstacles and cultivating a constructive rapport with mathematics. Nevertheless, it remains imperative to acknowledge that certain concerns and inadequacies necessitate resolution within the existing literature. This situation suggests that there remains untapped potential in the realm of MR, which warrants further investigation and offers substantial prospects for future scholarly inquiry. Therefore, further research is needed to thoroughly comprehend this topic and integrate it more effectively into educational practices. This comprehensive understanding is valuable for discerning how mathematical education and students can be empowered; however, it is necessary to integrate the structure of existing studies and map out a path for future research to ensure more effective practices.

3. The Rationale for the Research

Comprehending abstract concepts complicates the process of acquiring mathematics (MoNE, 2018). Misunderstanding or failing to comprehend these concepts can reinforce the perception of "I can't do it" resulting in a decline in mathematical achievement (Yenilmez & Özabacı, 2003). To overcome such challenges, the concept of MR has become significant (Johnston-Wilder & Lee, 2010). Despite the growing global interest, MR contains various ambiguities and deficiencies in its measurement and evaluation. In addition, a comprehensive understanding of the variables influencing MR and strategies for bolstering resilience among diverse populations is required. Therefore, it is necessary to conduct a review and gather research on MR.

In recent years, several reviews have been conducted on MR (Borazon & Chuang, 2023; Buckley & Sullivan, 2023; Johnston-Wilder et al., 2020; Ishak et al., 2020; Xenofontos & Mouroutsou, 2023). These studies, particularly empirical ones, have been conducted to investigate the notions of mathematical flexibility and academic resilience, with several approaches suggested to mitigate math anxiety and promote mathematical flexibility. Nevertheless, a comprehensive investigation into MR has yet to be undertaken. This systematic review holds significant value for individuals involved in the field of mathematics education, including educators and learners. This study seeks to broaden the body of knowledge and direct future research by providing information on MR-related articles. This strategy can foster greater originality in research endeavours. Periodic research on MR allows for tracking developments in the field, identifying knowledge deficits, and expanding knowledge (Ishak et al., 2020).

4. Aim of the Research

This research investigated the problem statement "What are the characteristics of studies conducted on MR?". In alignment with the specified objectives, this study seeks to address the following research questions:

Q1) What is the year-based distribution of studies on MR?
Q2) What is the distribution of studies on MR across various countries?
Q3) What is the prevalence of research methodologies utilized in studies on MR?
Q4) What is the prevalence of research methodologies utilized in studies on MR?
Q5) What are the typical sample sizes that researchers choose to use in studies on MR?
Q6) What are the types of samples that are typically picked in studies on MR?
Q7) What is the preferred distribution of collection tools utilized in studies on MR?
Q8) What are the data analysis techniques employed in research on MR?
Q9) What are the results of studies on MR?
Q10) What are the recommendations provided in studies on MR?

5. Method

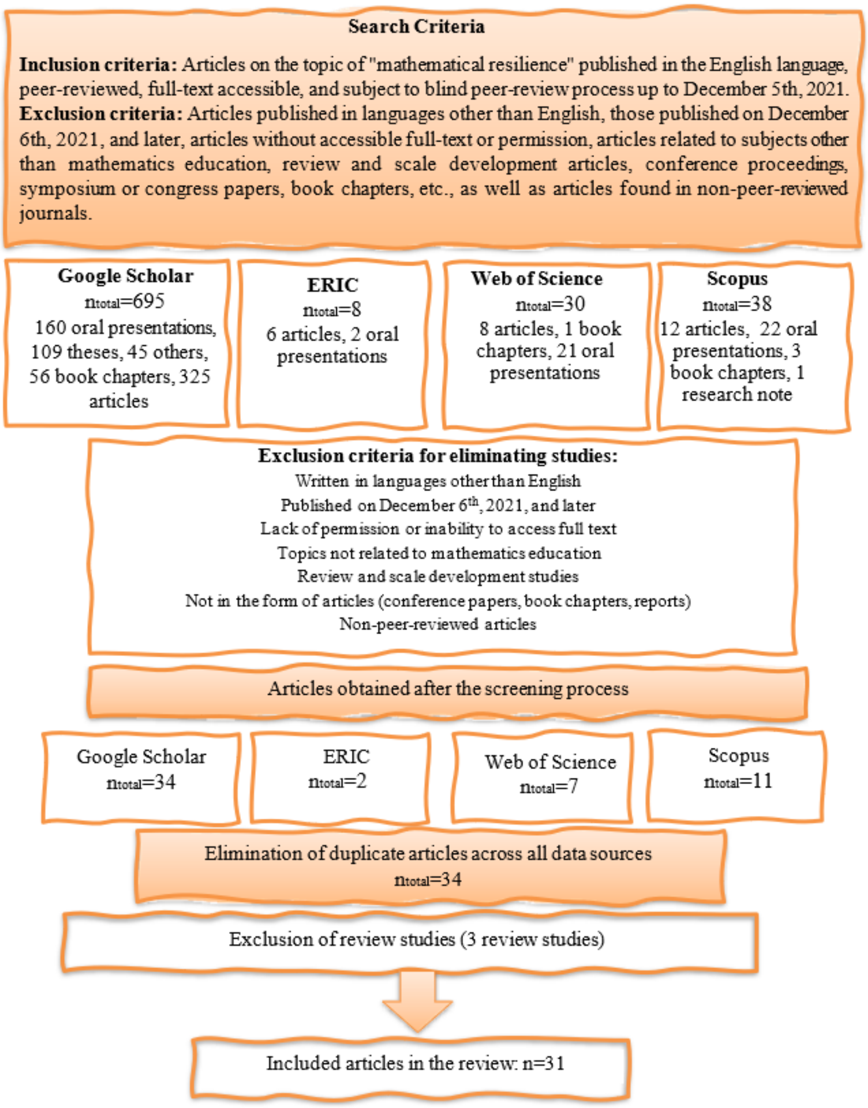
This study examined existing studies on MR. In line with this goal, a systematic review methodology was employed. A systematic review is a reassessment method that identifies, evaluates, and analyzes related studies using systematic methods. According to Bellibaş and Gümüş (2018), systematic reviews are typically conducted under three categories: meta-analysis, meta-synthesis, and descriptive content analysis. In this study, a descriptive content analysis focusing on MR was performed. In this context, peer-reviewed articles were systematically scrutinized.

5.1. Identification of Sources

This study involved conducting searches on various academic databases, including ERIC, Web of Science, Google Scholar, and Scopus. The search term "mathematical resilience" was selected. The research exclusively incorporated completely accessible publications authored in English. The articles encompassed in the research span from January 1, 2021, to December 31, 2021. The presence of duplicate articles was detected and subsequently eliminated. A total of 34 articles were obtained due to this procedure. Review papers were excluded, resulting in the inclusion of 31 publications that can be found labelled in the references section. The details of this procedure are illustrated in Figure 1.

Figure 1

Inclusion-exclusion criteria and the process of identifying sources



The first and second authors independently implemented the inclusion and exclusion criteria outlined in Figure 1 within the specified databases, each making separate efforts to discover. The researchers compared the stages derived from three separate online interviews, with each session having a duration of approximately three hours. The comparison revealed a compatibility rate of 85%. A complete consensus was achieved through deliberation on the conflicting sources. Upon the conclusion of this procedure, the articles encompassed within the study were assigned labels (A1, A2, ..., A31) and systematically arranged in preparation for data analysis.

5.2. Data Analysis

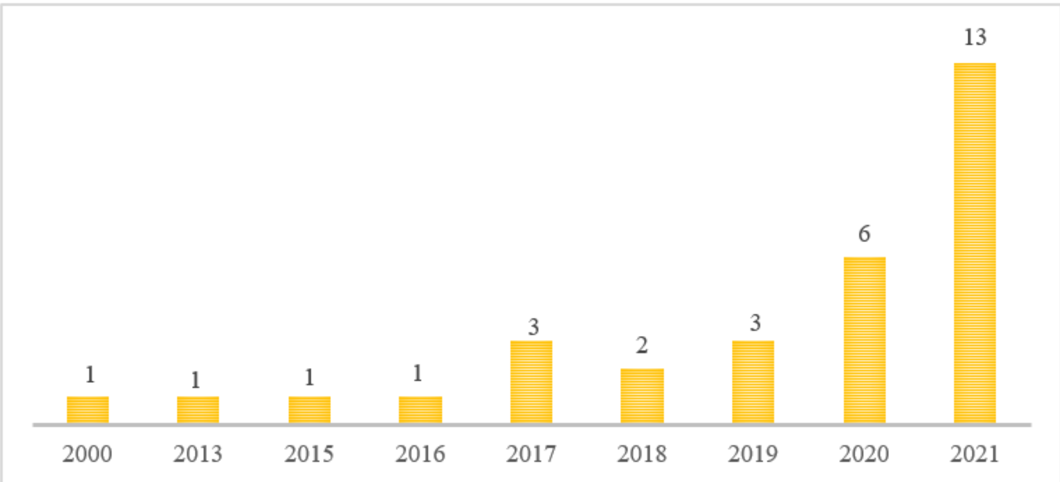
This study employed qualitative data analysis techniques, called descriptive analysis and content analysis. The objective of descriptive analysis is to draw quantitative conclusions by categorizing units that share similar characteristics or convey similar meanings (Elo & Kyngas, 2008). In contrast, content analysis involves the collection of similar data based on specific concepts and themes, followed by the organization and interpretation of this data in a manner that facilitates comprehension for the reader (Yıldırım & Şimşek, 2016). Descriptive analysis was employed to analyse the data of Q5, specifically focusing on the examination of sample sizes. Based on the provided information, the sample sizes were categorized into 14 distinct groups, namely 1-10, 11-50, 51-100, 101-150, 151-200, 201-300, 301-400, 401-500, 501-600, 601-700, 701-800, 801-900, 901-1000, and 1001 and above people. Content analysis was used in the analysis of data related to Q1, Q2, Q3, Q4, Q6, Q7, Q8, Q9, and Q10 of the research. During the content analysis process, the authors originally engaged in independent coding. Subsequently, upon encountering points of disagreement, they engaged in collaborative coding. The purpose of this action was to enhance the coherence of the analysis. The coding was subjected to comparative analysis and subsequent discussion until a consensus was reached. Upon the conclusion of the analytical procedure, the acquired findings were presented in the form of graphical representations, and frequency and percentage tables, with the intention of facilitating comprehension for readers.

6. Results

6.1. Distribution Based on Years

The distribution of studies undertaken on MR over the years is depicted in Figure 2. The study focused on a specific time frame spanning 22 years, ending in December 2021.

Figure 2
Distribution of studies by publication year



As Figure 2 clearly indicates, the first article on MR was published in 2000. However, following 2000, no articles were published on this topic for the next 13 years. Since 2015, studies on the topic of MR have been consistently published every year. Notably, in the years 2000, 2013, 2015, and

2016, a single article was published annually. The number of articles showed an upward trend beginning in 2017, with a total of two articles published in 2018, three pieces each in 2017 and 2019, and a notable increase to six articles in 2020. The year 2021 was identified as having the highest number of articles focused on MR.

6.2. Distribution Based on Country

Figure 3 displays the outcomes of the distribution by country of research on MR. In this context, the term 'country' does not pertain to the geographical location of the journal in which the paper was published, but instead signifies the nation from which the researchers who conducted the study originated. Figure 3 shows that studies addressing the topic of MR were authored by academics living in a total of eleven different countries. These countries include Indonesia, the United Kingdom [UK], the United States [US], Turkey, Germany, the Philippines, Spain, the Turkish Republic of Northern Cyprus [TRNC], Nigeria, Poland, and Portugal. The country with the greatest number of research completed on this topic is Indonesia, with a total of 14 studies. Following closely is the UK, with 8 studies conducted. The US identified two studies, but Turkey, Germany, Australia, the Philippines, South Africa, Spain, TRNC, Malaysia, Nigeria, Poland, and Portugal each published only one study.

Figure 3

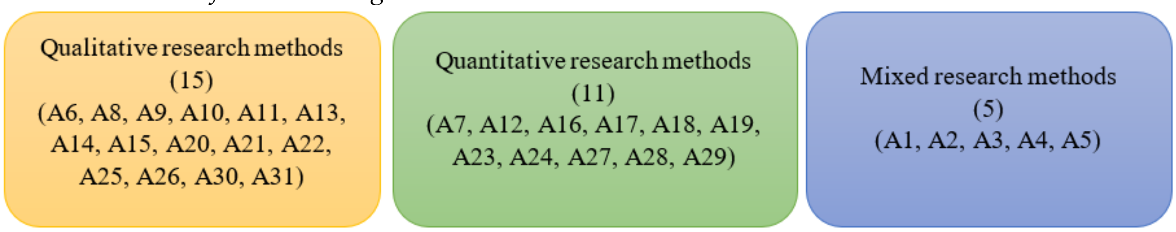
The distribution of studies by publication country

6.3. Preferred Research Method

Figure 4 shows the results of the allocation of studies on MR based on the employed research methods. In this analysis, studies are categorized into three distinct sections: quantitative research methods, qualitative research methods, and mixed research methods. According to Figure 4, it is evident that a considerable proportion of the articles were conducted using qualitative research methodologies (n=15, 48.4%). Qualitative research methods were followed by quantitative research methods (n=11, 35.5%), and the least preferred was mixed research methods (n=5, 16.1%).

Figure 4

The distribution of studies using research methods



6.4. Preferred Research Design

Table 1 presents the results of the allocation of studies on MR based on research designs. The articles were meticulously analysed in relation to quantitative, qualitative, and mixed research methods, in accordance with the conclusions derived from the preceding study problem. As Table 1 clearly indicates, a considerable proportion of studies pertaining to MR utilized qualitative research methods. These methods primarily involve descriptive approaches, constituting 19.4% of the total sample size (n=6). In qualitative studies, specifically 16.1% (n=5), the designs employed were not explicitly stated. Other qualitative research methods were case studies, which accounted for three out of the total sample size (9.7%), and phenomenology, which was represented by a single study (3.2%).

In the studies that used quantitative research methods, it was shown that experimental studies were more commonly favoured (n=6, 19.4%) compared to non-experimental studies (n=4, 12.9%). In addition, one article did not specify the study design. The predominant focus of the studies in this study belonged to quasi-experimental designs (n=4, 12.9%). However, the actual experimental design and single-subject designs were explored in only one article each. In relation to non-experimental designs, correlational research accounted for the majority (n=3, 9.7%), while only one article conducted a survey study.

In studies, a mixed-methods approach was employed, incorporating both explanatory sequential and embedded designs, each accounting for 6.5% of the total (n=2). It is noteworthy that one study did not explicitly specify its research design.

Table 1
The distribution of studies using research methods and designs

Method and Research Design	*n*	*%*	*Articles*
Qualitative			
The case study	3	9.7	A13,A15,A30
Phenomenology	1	3.2	A6
Qualitative descriptive research	6	19.4	A8,A9,A10,A11,A14,A25
Unspecified design	5	16.1	A20,A21,A22,A26,A31
Quantitative			
Experimental design			
Actual experimental design	1	3.2	A27
Quasi-experimental design	4	12.9	A12,A18,A24,A28
Single-subject design	1	3.2	A17
Non-experimental designs			
Correlational	3	9.6	A16,A19,A29
Survey	1	3.2	A23
Unspecified design	1	3.2	A7
Mixed			
Explanatory sequential	2	6.5	A2,A5
Embedded	2	6.5	A1,A3
Unspecified design	1	3.2	A4
Total	31	100	

6.5. Preferred Sample Sizes

Table 2 presents the results of the preferred sample sizes utilized in studies focusing on MR. According to Table 2, it can be observed that most sample sizes in research on MR fall within the ranges of 11-50 and 51-100 (n=7, 22.5%). Subsequently, a series of studies were examined, where the sample size varied between 1 and 10 (n=6, 19.4%). The results presented suggest that the sample sizes in most of the studies examined range from 1 to 100. The less frequent selection of other sample sizes was observed. For example, three studies (9.7%) were conducted with a sample

Table 2
The distribution of studies by sample size

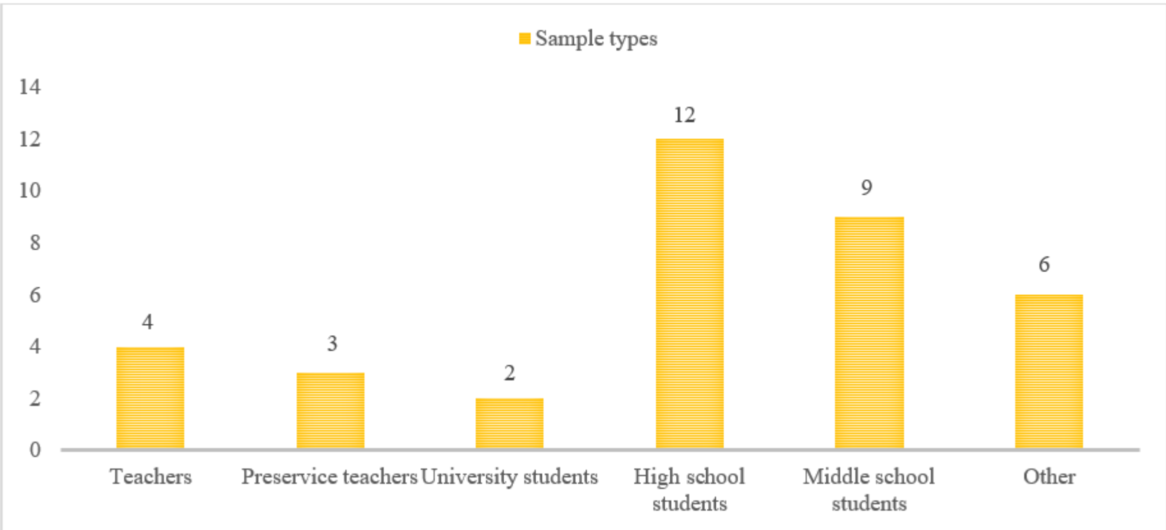
Sample Sizes	*n*	*%*	*Articles*
1-10	6	19.4	A3,A6,A13,A15,A17,A30
11-50	7	22.5	A4,A5,A14,A18,A20,A21,A23
51-100	7	22.5	A1,A2,A7,A9,A12,A22,A27
151-200	1	3.2	A28
201-300	2	6.5	A25,A31
401-500	2	6.5	A10,A24
801-900	3	9.7	A8,A11,A19
1001 and above	2	6.5	A16,A29
Unspecified	1	3.2	A26
Total	31	100	

size ranging from 801 to 900. Similarly, two studies each were identified in the sample size ranges of 201-300, 401-500, and 1001 and above. Only a single study (n=1, 3.2%) had a sample size ranging from 151 to 200. Furthermore, a single study (n=1, 3.2%) was identified in which a specific sample size was not provided.

6.6. Preferred Sample Types

Figure 5 illustrates the distribution of sample types assigned in studies of MR. The preferable sample types for studies include individuals such as teachers, teacher candidates, university students, high school students, middle school students, and others.

Figure 5
The distribution of preferred sample types



The majority (n=12, 38.7%) of studies on MR focused on high school students, as shown in Figure 5. Middle school students (n=9, 29%) and other sample types, including diverse demographic groups such as parents, researchers, and engineers (n=6, 19.4%), were the next most frequently targeted groups. Furthermore, studies on MR were conducted with a sample of teachers (n=4, 12.9%), preservice teachers (n=3, 9.7%), and university students studying in disciplines such as nursing and engineering (n=2, 6.5%). However, it is noteworthy that there are no existing studies with preschool and elementary school students on MR.

6.7. Utilization of Data Collection Tools

Table 3 represents the distribution of the data collection tools utilized in studies pertaining to MR. The data collection tools employed in this study encompassed a range of instruments, such as field notes questionnaires, documents, inventories, interviews, observations, scales, and tests.

Upon examining Table 3, it becomes apparent that studies focusing on MR utilized a variety of data collection tools. The data collection tools most frequently used were surveys (n=21, 67.7%) and interviews (n=16, 51.6%). On the other hand, document analyzes and tests (n=9, 29%), and scales (n=7, 22.5%), were less typically employed. Meanwhile, the use of field notes (n=4, 12.9%), observations (n=3, 9.7%), and inventories (n=1, 3.2%) as data collection tools was comparatively low.

Table 3

The distribution of studies using data collection tools

Tools	*n*	*%*	*Articles*
Field notes	4	12.9	A6,A20,A30,A31
Questionnaire	21	67.7	A1,A2,A4,A5,A7,A8,A9,A10,A11,A12,A14,A18,A19,A22,A24, A25,A27,A28,A29,A30,A31
Document	9	29	A5,A9,A10,A17,A20,A24,A25,A30,A31
Inventory	1	3.2	A24
Interview	16	51.6	A1,A2,A4,A5,A6,A9,A10,A13,A14,A15,A20,A21,A23,A25,A26,A30
Observation	3	9.7	A1,A5,A17
Scale	7	22.5	A3,A7,A16,A19,A23,A24,A29
Test	9	29	A1,A2,A3,A5,A12,A18,A19,A27,A28

6.8. Utilization of Data Analysis Techniques

The results related to the data analysis techniques employed for studies on MR are displayed in Table 4. The examination of the data analysis techniques was conducted within the structures of both quantitative and qualitative procedures. Furthermore, this study investigated two distinct types of quantitative data analysis techniques, namely descriptive and inferential statistical techniques. Similarly, qualitative data analysis techniques were categorized into three distinct sections, namely descriptive analysis, content analysis, and other.

Table 4

The distribution of studies using data analysis techniques

Data analysis techniques	*n*	*%*
Quantitative data analysis (n=20, 64.5%)		
Descriptive statistics (n=16, 51.6%)		
Frequency-percentage tables	7	22.5
Mean	10	32.3
Standard deviation	5	16.1
Graphical representation	4	12.9
Inferential statistics (n=15, 48.4%)		
Correlation	4	12.9
t-test	5	16.1
ANOVA	4	12.9
Factor analysis	1	3.2
Regression	5	16.1
Structural equation modelling	1	3.2
Kolmogorov-Smirnov	2	6.5
Mann-Whitney U test	1	3.2
Wilcoxon signed rank test	1	3.2
Other: Sobel test	1	3.2
Other: Rasch Model	3	9.7
Qualitative data analysis (n=21, 67.7%)		
Content analysis	12	38.7
Descriptive analysis	10	32.3
Other	1	3.2

Table 4 reveals that studies of MR exhibit a greater emphasis on qualitative data analysis as opposed to quantitative data analysis. The utilization of descriptive and inferential statistics in quantitative data analysis appears to be a bit equivalent to the utilization of content and descriptive analysis in qualitative data analysis. However, it was discovered that descriptive statistics in quantitative data analysis and content analysis in qualitative data analysis are particularly prominent. In qualitative data analysis techniques, content analysis was the most used technique, accounting for 38.7% of the total sample size (n=12). Following this, descriptive analysis in qualitative data analysis and the mean technique in quantitative descriptive statistics were also commonly utilized (n=10, 32.3%). The use of several data analysis techniques was observed in the field of quantitative descriptive and inferential statistics. Frequency-percentage tables (n=7, 22.5%), standard deviation (n=5, 16.1%), t-tests (n=5, 16.1%), and regression procedures (n=5, 16.1%) were among the often-employed techniques. Conversely, several quantitative inferential statistical techniques, namely factor analysis, structural equation modelling, Mann-Whitney U test, Wilcoxon signed-rank test, and Sobel test, were employed infrequently (3.2%). Consequently, these techniques were considered less favoured among the data analysis techniques.

6.9. Results from the Studies

The results of studies on MR focused on five key headings: cognitive, affective, pedagogical, demographic, and social features. Themes such as mathematical process skills, mathematical skills, and mathematical competence were identified as the key cognitive aspects in the obtained results (see Figure 6).

Figure 6
Results on cognitive features

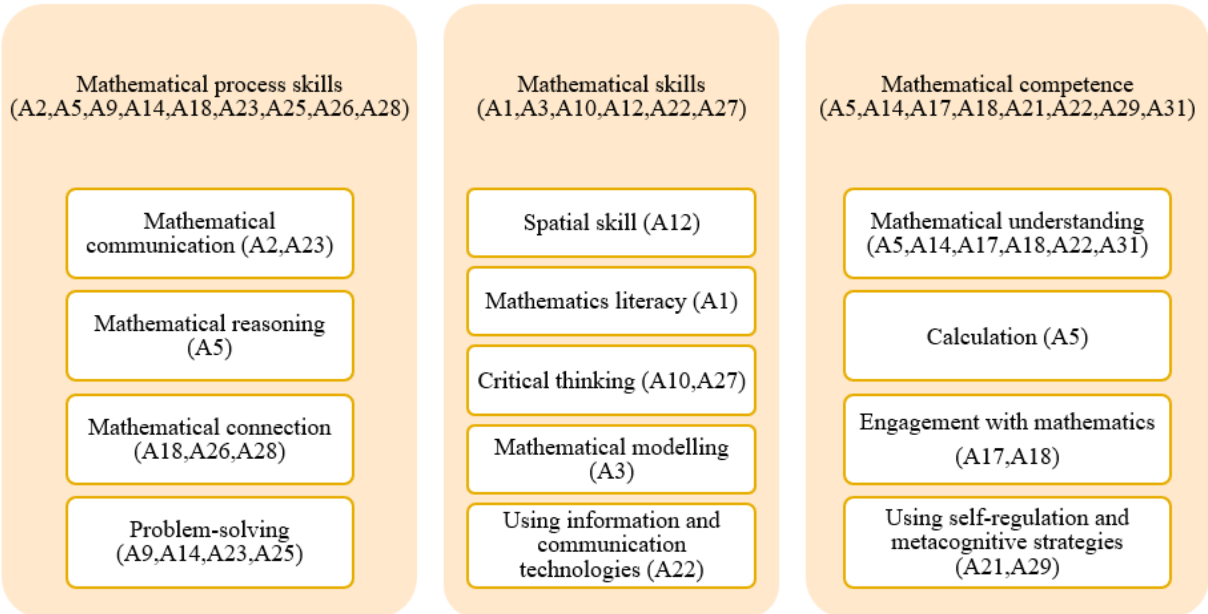


Figure 6 illustrates that mathematical process skills comprise various components, namely mathematical communication, mathematical reasoning, mathematical connection, and problem-solving skills. *Problem-solving skills* comprise the ability to navigate through various scenarios and effectively address faults. According to A9, there exists a positive correlation between high MR among slow learners and their ability to solve mathematical problems, whereas medium and low MR have an inverse relationship with this skill. A23 underscores the importance of diligent and flexible problem-solving skills among high-achieving students, whilst A25 highlights the varying abilities of participants in addressing questions related to higher-order thinking skills. According to A14, a correlation exists between the level of MR and the occurrence of verbal problem-solving errors among students. Additionally, it was observed that students with higher levels of MR demonstrated greater accuracy in answering the questions. The studies investigated the *mathematical connections* inherent in the utilization of various representations, real-world scenarios, and mathematical puzzles. A18 examined the impact of utilizing Google classroom-based learning on students' mathematical representation skills, whereas A26 emphasized the role of incorporating daily life scenarios and puzzles to foster mathematical discussions. A28 indicated that the effects on connecting abilities varied for students with MR and that there was no interaction between mathematical connection ability and the Treffinger learning model.

Mathematical communication places a strong emphasis on students' capacity to engage in discussions and modify their thinking within classroom settings. According to A2, there is no difference in mathematical communication between module-supported and e-learning-aided learning, and high MR does not always imply improved communication abilities. On the contrary, A23 underscores the variability in communication abilities based on students' levels of MR. Furthermore, A5 highlights that students who possess a strong level of MR have demonstrated proficiency in the domain of *mathematical reasoning*.

The second cognitive feature, denoted as mathematical skills, comprises a range of abilities, including spatial skills, mathematical literacy, critical thinking, mathematical modelling, and the use of information and communication technology (ICT). According to the results of A27 and A10, no discernible correlation exists between *critical thinking* and MR. A12 focuses on the use of a blended learning rotation model to enhance the MR of high school students, specifically in relation to their *spatial skills*. In A12, the utilization of this model demonstrated a significant enhancement in students' mathematical spatial skills compared with those taught using traditional methods. According to A1, the MR exhibited by students plays a significant role in their attainment of *mathematical literacy*. This resilience is crucial in effectively addressing and resolving mathematical problems that require a high level of numeracy skills. A3 focusing on *mathematical modelling* found a notable improvement in the model-building skills of teacher candidates who participated in the Mathematical Modelling Education Program. According to A22, students perceived the use of ICT in mathematics as advantageous and valued the practical learning environment it fosters.

Mathematical competence encompasses a comprehensive range of abilities, including mathematical understanding, calculation skills, engagement with mathematics, utilization of self-regulation, and implementation of metacognitive strategies. *Mathematical understanding* is often characterized as the ability to grasp mathematical concepts and the potential to improve one's mathematical learning. For instance, A22 indicated that the utilization of TinkerPlots software was proven to be advantageous for students in comprehending mathematical concepts. As stated in A31, the empowerment, and authorization of students play a crucial role in enhancing their mathematics learning outcomes. In contrast, A14 indicated that individuals who have low MR exhibit mistakes in comprehension while attempting to solve verbal problems. The competence of *engaging with mathematics* was addressed in A17 and A18. Accordingly, the participation of adults in the Conjoint Behavioural Consultation can foster favourable associations between students and mathematics. *Calculation* competence was addressed in A5, which highlights students with a moderate level of MR who exhibit lower proficiency in making mathematical predictions. Additionally, students with a low level of MR demonstrated an inability to make predictions and execute mathematical operations. A21 and A29 showed evidence of a beneficial association between *self-regulation and metacognitive strategies*, and their impact on academic performance. According to A21, there was an observed increase in access to "Further Mathematics" through self-regulation. Furthermore, A29 emphasized the favourable correlation between MR and metacognitive strategies in relation to academic performance.

The prominence of affective features in the context of achievement and psychological condition was observed in studies pertaining to MR (Figure 7). In this regard, in the findings related to affective features, the processes influencing achievement are associated with educational concepts, whilst the internal processes independent of success are linked to affective processes influencing psychology.

Figure 7
Results on affective features (Source: Authors' own illustration)

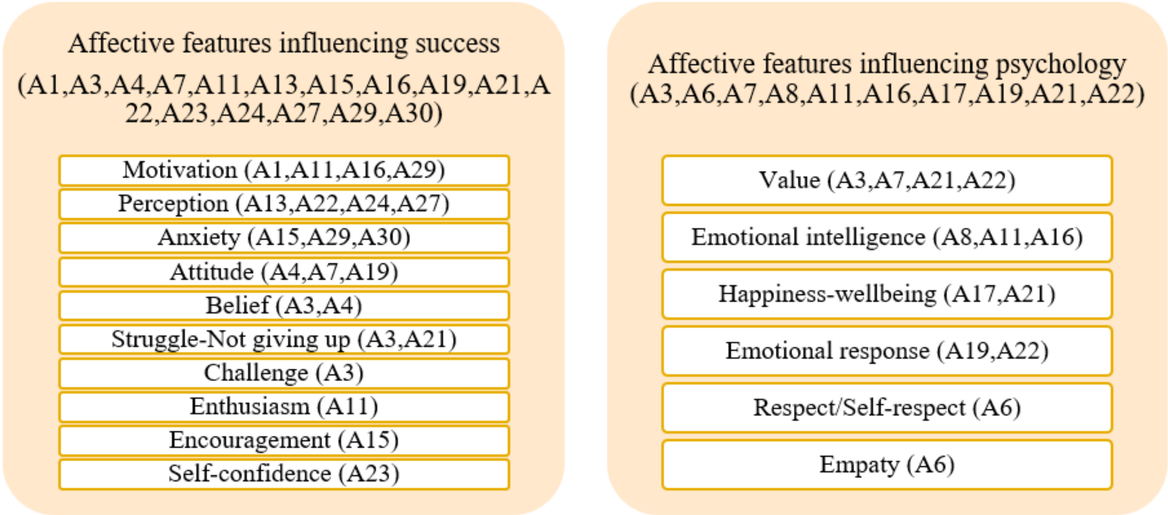
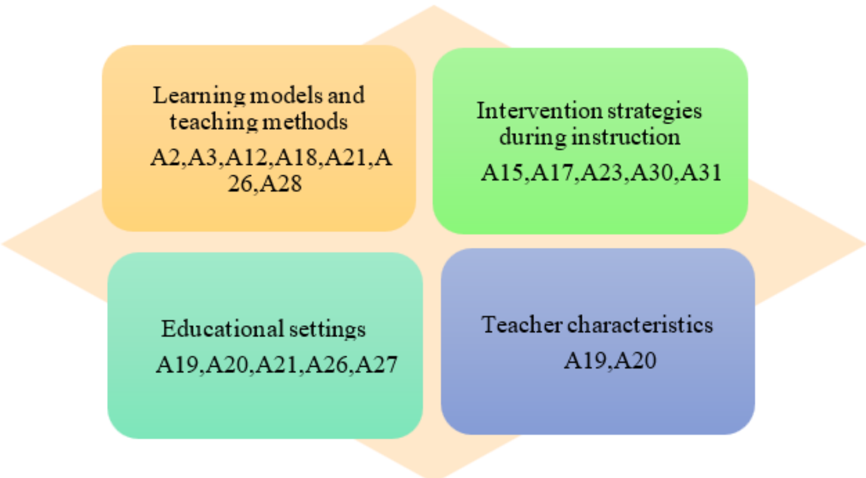


Figure 7 illustrates that several affective features, including motivation, perception, anxiety, attitude, belief, striving and challenge-seeking, enthusiasm, encouragement, and self-confidence, influence success. *Motivation*, in addition to being widely regarded as an affective feature that influences success, has been specifically examined in relation to learning and achievement. In A1, a comparative analysis was conducted on the mathematical literacy skills of students with varying learning motivations. The results of this study indicate that there may not always be a clear correlation between motivation and the acquisition of mathematical literacy skills. A29 highlighted the significant correlation between MR and motivation, as well as metacognitive strategies. A16 stated that Nigerian students could gain MR with achievement motivation and appropriate emotional intelligence strategies. In contrast, A11 highlighted that heightened motivation can occasionally result in adverse outcomes for students with low levels of MR. The study also underscored the significance of *enthusiasm* within the motivation component. Negative experiences, distress, and a *perception* of discomfort have also been acknowledged as affective features. A13 noted that continually seeking ways to counteract unfavourable elements can contribute to the development of MR. Several studies have established a connection between *anxiety* and success, specifically in relation to MR. For instance, A29 underscored the significance of MR in mitigating students' math anxiety and enhancing their academic performance. Additionally, A30 demonstrated the efficacy of peer intervention in reducing mathematical anxiety and fostering MR. A4 and A7 indicated that students' mathematical *attitude* plays a crucial role in determining their MR, with negative attitudes being detrimental to this MR. According to A19, there is a correlation between school attitude and MR. Beliefs about mathematics and learning-doing mathematics play a significant role in influencing success within affective attributes. According to A3, there is evidence to suggest that MR has a positive impact on individuals' *beliefs*. Nevertheless, according to A4, students who hold the belief that they lack mathematical abilities and struggle to provide prompt and precise responses in the classroom tend to disengage themselves from valuable and fulfilling opportunities. A3, addressing affective processes of engagement with *challenging* various difficulties, *struggling* with them, and *not giving up*, indicated that students who actively confront obstacles and exhibit MR in pursuit of mathematical modelling skills are more likely to comprehend the value of mathematics. Affective features such as *encouragement* have also been examined. A15 indicated that the cultivation of MR is indispensable in a learning-conducive setting. Finally, A23 revealed that diligence, *self-confidence*, and problem-solving capabilities are paramount factors in determining MR among high achievers.

The second set of results related to affective features pertains to the factors influencing psychology. These factors include *respect for others and oneself*, *emotional intelligence*, *happiness and well-being*, *emotional responses*, *values*, and *empathy* skills among individuals. A6 observed that a reciprocal exchange of MR occurred between teachers and students, as they showed *empathy* toward each other's mathematics anxieties. This finding underscores the crucial roles that empathy, respect for others, and self-respect play in the development of MR. *Emotional intelligence* is an essential characteristic that has a significant impact on psychological conditions. In A8, it was observed that emotional intelligence exhibits a discernible impact on the MR of students. A11 examined the correlation between MR and emotional intelligence, while A16 explored the impact of emotional intelligence on MR. A17 addressed the impact of the conjoint behavioural consultation intervention on the enhancement of MR and its implications for overall *well-being.* A17 documented positive changes in the handling of the well-being factor after its implementation. The examination of individuals' *emotional responses* to various stimuli, events, memories, and thoughts was explored in A19 and A22. A19 found a significant correlation between teachers' performances and positive effects. Conversely, A22 reported that a minimal number of students expressed indifference toward the use of ICT during mathematics lessons. The notion of *value* assumes significance in the context of MR by emphasizing the recognition and utilization of the intrinsic worth of mathematics. A3, A7, A21, and A22 revealed a significant correlation between the intrinsic worth of mathematics and subjective experiences of pleasure and appreciation. In A7, it was observed that engineering students possess a strong recognition of the significance of mathematics in relation to their professional career paths.

The results pertaining to pedagogical features refer to the various methods and learning models employed in the process of teaching, the intervention strategies implemented during instruction, the educational settings, and the characteristics of the teachers involved (see Figure 8).

Figure 8
Results on pedagogical features



The results of learning models and teaching methods are depicted in Figure 8, which displays the diverse impacts of different learning models and instructional methods on students' MR and skills. As an illustration, the results of A2 revealed that certain instructional approaches enhanced MR, while no significant impact was observed on mathematical communication skills. The results of A3 indicated that the 12-hour mathematical modelling training provided to the teacher candidates had a beneficial effect on their perceptions of mathematical modelling and MR. In A12, various learning models were examined, and it was determined that blended learning and cognitive conflict strategies exhibited a greater impact on enhancing MR than compared to conventional approaches. Furthermore, it was ascertained that the blended learning model had an interactive effect on students' baseline mathematical abilities. A18 demonstrated that the implementation of Google Classroom-based blended learning had a favourable impact on students' MR when compared with the traditional instructional model. According to A21, the incorporation of blended learning into the mathematics curriculum for those aged 16 and above would enhance their MR. A26 argued that the inclusion of daily life events and mathematical puzzles in educational settings fosters the development of mathematical discourse and MR among young children. Finally, A28 indicated that there was no significant correlation between Triffinger and conceptual learning models in relation to MR and mathematical connection skills.

Results of intervention strategies employed during instructional practices suggest that educational institutions have implemented supportive, collaborative, and peer interventions to enhance teaching processes. Within this setting, the significance of self-determination theory in augmenting MR through the establishment of supportive atmosphere was underscored by A15. According to A17, collaborative interventions had the potential to promote adaptable behaviour in both home and school settings. A30 indicated a reduction in levels of mathematics anxiety following the implementation of peer intervention. A31 emphasized that the involvement of students in active roles had the potential to boost their mathematics learning.

Results of educational settings primarily focus on the structure and layout of instructional settings, as well as key aspects related to the capacity for fostering mathematical depth and complexity. For instance, A19 discovered that the architecture of the home-school mesosystem failed to have a statistically significant influence on student achievement. The significance of the tools utilized by teachers in fostering MR was highlighted in A20. A26 asserted that educational settings possess the capacity to foster a mathematical depth, while parents and preschool teachers were observed to have the ability to cultivate children's MR.

Results of teacher characteristics mostly centre on teacher competencies and the significance of teachers' perspectives on MR. As an example, A19 asserted that the pedagogical competencies of teachers have a favourable impact on the MR of students. Contrarily, A20 posited that the implementation of the lesson format facilitated the application of ideas related to MR, thus enhancing instructors' cognitive processes and efficacy in the topic.

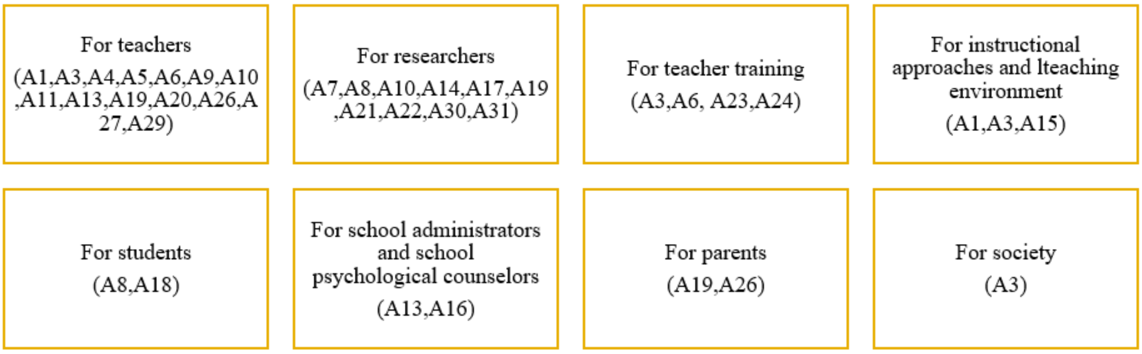
Results of demographic characteristics focus on the effects on students' MR and attitudes within the context of institutional and transdisciplinary variations, disparities in learning pace, and individual characteristics. For instance, A4 examined students from several educational institutions and found that they exhibited a more favourable disposition toward mathematics. A7 examined the interdisciplinary disparities between students majoring in engineering and nursing. Their findings revealed that students generally, exhibited a favourable disposition toward mathematics. However, engineering students showed a marginally more favourable attitude in comparison. A9 found a positive correlation between high MR and problem-solving abilities among slow-learning children. However, it was observed that these students typically did not fully complete the solution processes. A21 conducted a study that examined gender differences by focusing on individual features. On the other hand, A8 conducted research to explore the association between gender and emotional intelligence, with the conclusion that gender does not have an impact on emotional intelligence.

Results of social characteristics focus on the impact of family, peers, teachers, counsellors, and educational settings on the development of MR. For example, A13 underscored the crucial role that family members and caregivers play in fostering MR. A23 observed that the act of socializing and cooperating with peers correlates with diminished levels of MR. Several more studies examined the wider societal circumstances. For example, A19 articulated that social characteristics such as the home environment and relationships with parents are instrumental in predicting student success, but the interaction between home and school does not manifest a discernible effect. A18 found that the implementation of the "Conjoint Behavioural Consultation" approach resulted in favourable outcomes, highlighting the significance of collaboration among family members, teachers, and counsellors. A21 examined the impact of peer support, parental support, school support, and gender differences.

6.10. Recommendations from Previous Studies

Studies on MR encompass a range of recommendations for different stakeholders, including teachers, researchers, teacher training, instructional approaches and teaching environments, students, school administrators, school psychological counsellors, parents, and the wider society (see Figure 9).

Figure 9
Recommendations given in the studies



The recommendations provided in Figure 9 primarily pertain to instructional strategies, pedagogical environments, and affective aspects, with a specific emphasis on *teachers*. The significance of emotional intelligence and the dissemination of positive emotions by teachers both inside the classroom and in interactions with parents is underscored. Within this framework, teachers are recognized as having a significant role in augmenting MR. Several studies (A5,A27) highlighted the need for teachers to foster MR among their students, as emphasized by article A3, which also underscores the necessity of initiating this process at an early stage. In addition, actionable recommendations for teachers in the field have been provided. A20 and A4 emphasized pedagogical changes and the use of interactive teaching methods. Articles A10 and A9 focused on the development of critical thinking and problem-solving skills. A29 highlighted the significance of the classroom environment and the practical application of mathematical concepts. The studies, A19, A26, and A29, highlighted the significance of pedagogical and affective aspects. They also emphasized the importance of teachers establishing autonomous learning settings and enhancing teacher-student interaction. Finally, A13 underscored the significance of disseminating MR and growth models to parents.

Recommendations for researchers focused on the importance of conducting further research with diverse samples and contexts. A7, A8, A17, and A30 emphasized the necessity of obtaining a comprehensive and varied sample. A8 and A17 underscored the significance of enhancing diversity within a wide-ranging population, while A30 noted the need to consider the methodologies employed in studying mathematics anxiety and MR. A8 proposed a concentration on the examination of mathematical thinking and MR. A17 recommended the development of innovative studies and a focus on pedagogical characteristics. A10 focused on diverse materials and the cultivation of critical thinking abilities. Meanwhile, A14 and A22 emphasized the importance of long-term studies and technology. Moreover, A21 emphasized the significance of incorporating pedagogical, cognitive, and affective aspects, while A14 and A31 highlighted the necessity of filling the gaps in literature regarding MR. The recommended alterations in methodology encompassed the use of longitudinal studies as opposed to cross-sectional studies (A19, A30), and the use of single-subject experimental designs in diverse populations (A17).

Recommendations for teacher training were made from affective, cognitive, and pedagogical standpoints. Several articles, namely A6, A23, and A24, underscored the significance of concentrating on mathematical competence, mathematical ability, and affective domains in the context of teacher education. A23 recommended the augmentation of MR in pre-service teachers, whereas A24 advocated for the exploration of said MR in relation to student achievement. A3 has brought to the forefront the significance of incorporating mathematical modelling and MR into both pre-service and in-service teacher training programs.

Recommendations for instructional approaches encompass both affective and cognitive contexts. A1 posited that digital tools possess the capacity to augment the impetus to learn and mathematical literacy skills. Meanwhile, an emphasized the criticality of *teaching environments* that are conducive to mathematical modelling. A15 proposed teaching environments that cultivate MR and cater to the varied needs of students, encompassing the provision of optional learning opportunities, engaged teachers, a climate of respect, and feedback mechanisms aimed at bolstering student aptitude.

Recommendations for students encompass affective, cognitive, and pedagogical contexts. A8 underscored the significance of developing MR and emotional intelligence as deficiencies in these areas can impede learning. Additionally, A18 highlighted the potential of blended learning, a hybrid approach that combines traditional classroom instruction with online learning, to facilitate the identification and cultivation of active learning styles among students.

Recommendations for school management and school psychological counsellors highlight the significance of MR in various contexts such as affective, social, and pedagogical. A13 advocated that schools must acknowledge the effects of MR for both parents and students and promote it in society, whereas A16 drew attention to the vital role of school administrations and psychological counsellors in introducing MR to their students. Furthermore, it was recommended that psychological counsellors prioritize mathematical adjustment over mathematical anxiety and organize motivational activities.

Recommendations for parents underscore the crucial nature of their involvement in their children's education and its impact on their mathematical achievement. A19 posited that parents ought to give their children affirmative academic backing, whilst A26 highlighted the insufficiency of math-oriented incentives. This article suggested that introducing children to mathematical discourse at a young age can bolster their MR and that parents may require guidance in this regard. Finally, A3, which offered *societal recommendations*, asserted the necessity of promoting awareness regarding MR throughout the broader community, commencing from the early stages of preschool education.

7. Discussion, Conclusion and Recommendations

The emergence of MR as a prominent subject in academic discourse, particularly in education, necessitates a sophisticated understanding of its development and impact. This systematic review offers valuable insights into current trends and potential future research directions, underscoring MR's significance in educational settings. It serves as a crucial resource for researchers in mathematics and engineering, informing, and guiding their work.

Significant progress in MR research was observed from 2000 to 2021. Research began in 2000, but substantial research only emerged in 2013. Limited publications in the early years may reflect challenges in establishing MR as a field. Increase in publications from 2017, reaching a peak in 2020 and 2021, indicates growing acknowledgment of MR. This trend suggests that MR is an evolving field with areas awaiting deeper exploration. The recent surge in MR research may be due to its increased relevance in sectors like education and psychology (Johnston-Wilder et al., 2021; Lee & Johnston-Wilder, 2017). The novelty of MR implies ongoing adaptation to various contexts and a growing interest in applying it in learning and problem-solving (Attami et al., 2020; Cahyaningsih et al., 2021; Faradillah & Fadhilah, 2021; Hafiz et al., 2017; Rohmah et al., 2020b). Systematic reviews play a crucial role for analyzing these trends, identifying research gaps, and suggesting future directions for MR, particularly in educational settings (Borazon & Chuang, 2023; Xenofontos & Mouroutsou, 2023).

The worldwide contributions to MR literature, originating from researchers across different regions highlight MR's universal significance and practicality of MR in various educational contexts. The UK's and Indonesia's focus on educational innovation (Kristiansen & Pratikno, 2006;

Rahmadi & Lavicza, 2021; Skipp & Dommett, 2021) shows potential disparities in national research priorities or educational challenges. The popularity of research conducted in Indonesia can be attributed to country’s specific educational demands and policies. Indonesia's emphasis on MR may be influenced by its difficulties faced by its educational system, as demonstrated by the performance of Indonesian students in PISA assessments (Mailizar et al., 2014). Indonesia’s educational policies since 1994 have emphasized enhancing students’ logical reasoning and problem-solving skills, impacting the type and amount of MR research conducted in the country. This association between national educational policies and the emphasis on academic research justifies further examination (Sá et al., 2013). Indonesia’s current circumstances provide significant knowledge for other nations in addressing educational difficulties. It demonstrates how certain educational policies can influence the focus on research the results obtained, making MR a more significant concept in addressing educational difficulties (Buracas & Navickas, 2017; Harris & Jones, 2017).

Approximately half of the MR studies employed qualitative methodologies, emphasizing the importance of an inductive approach for understanding of MR. Qualitative designs namely case studies, phenomenology, and descriptive research offer in-depth insights into MR’s intricate nature. However, there is a lack of action research and critical studies in MR research. Incorporating these methodologies could substantially benefit teaching practices and support children with low MR (Quijada Cerecer et al., 2013). Action research, focusing on practical solutions (Büyüköztürk et al., 2010, p.279), and critical studies, which seek to comprehend and alter social processes (İzci, 2015, p.418), can provide invaluable contributions to the field by offering practical, realistic insights and solutions (Lescano et al., 2019). On the other hand, quantitative methodologies were also commonly used in MR studies, allowing for establishing causal linkages, making predictions, and constructing generalizations (Wu & Little, 2011). Designs such as experimental, quasi-experimental, single-subject, correlational, and survey methods were frequently employed. Quasi-experimental and correlational designs play a crucial role in examining relationships in MR. These methodologies enable researchers to investigate relationships without manipulating variables (Büyüköztürk et al., 2010, p. 226), thereby broadening the understanding of MR. However, underutilized approaches such as causal comparison, comparative correlational studies, and structural equation modelling could provide a more comprehensive understanding of MR. The use of mixed-methods research in MR studies is limited, but it could offer a more holistic view of MR by integrating quantitative and qualitative data. This integration could significantly expand knowledge of MR across different educational settings, using the strengths of both quantitative and qualitative approaches.

A discernible trend exists in the selecting of sample sizes. The ranges like 101-150, 301-400, 501-800, and 901-1000 were often ignored, while large sample groups were rarely employed. This trend suggests that researchers may prioritize depth over breadth in their investigations, aiming for precise insights instead of broad generalizations. The preference for small sample sizes indicates a desire for exhaustive, qualitative inquiry, allowing researchers to thoroughly explore the intricate features of MR. Nevertheless, this approach may limit the generalizability of findings (Creswell & Poth, 2018; Merriam & Tisdell, 2015; Patton, 2015). Although small sample sizes have advantages in performing extensive analysis, including larger sample sizes could improve the representativeness and practicality of the research (Patton, 2015). A balanced perspective is essential for understanding MR in various populations and contexts. The existing research highlights the need to use qualitative methodologies in exploring the intricate facets of MR. Qualitative methodologies are crucial for comprehending the complexities of this subject, but the combination of qualitative studies with larger sample sizes has not been thoroughly investigated. This integration has the potential to provide a comprehensive perspective by combining in-depth qualitative insights with the ability to generalize based on larger samples. Future studies should prioritize examining this equilibrium to enhance our comprehension of MR and its consequences among various demographics. (Edwards et al., 2021).

The literature on MR among high school and middle school students is extensive, but there is a noticeable gap in studying teachers and university students. It is noteworthy to study essential role of teachers in cultivating students' MR as it directly affects how students overcome mathematical difficulties. Longitudinal studies involving teachers can give deeper insights into how their teaching strategies impact the development of MR over time (Buckley & Sullivan, 2023; Tambunan, 2021). Furthermore, the lack of study on MR among preschool and primary school students, which is noteworthy considering the importance of fundamental mathematical concepts are acquired during these early stages. Enhancing MR in young learners can lead to significant improvements in skills (Magnuson et al., 2016; Nguyen et al., 2016). Conducting experimental studies or action research during these educational phases can provide valuable insights into MR's development from an early age. This gap in this area indicates the necessity for a more detailed investigation of MR across various educational levels. Studying MR in early childhood and elementary school can shed light on its initiation and development, offering useful insights for educational approaches. Such studies can fill a critical gap in the literature and guide for educators and policymakers in designing early educational curricula and interventions (Pieronkiewicz & Szczygieł, 2020). Ultimately, research that includes educators and younger students is needed to enhance our understanding of MR across various educational levels and circumstances.

In MR studies, various data collection tools have been employed, with particularly surveys and interviews. According to Odabaşı (1999), surveys are a systematic method for collecting data, essential for evaluating the growth and advancement. This approach enables researchers to acquire a thorough comprehension of the existing condition and progression of MR. Interviews are useful for exploring individuals' cognitive and affective states, as suggested by Türnüklü (2000). They provide a more profound understanding of how MR impacts individual cognitive processes, emotional experiences, and behavioral patterns. However, the dependence on surveys and interviews also underscores the necessity for broader methodological diversity in MR research. Alternative data collection tools, such as worksheets, rubrics, diagnostic tests, and inventories, capture the complexity of MR from different perspectives. This variety of tools recognizes that no single approach can fully capture MR's complex characteristics. The inclusion of numerous tools enables a more comprehensive evaluation of MR, considering different facets such as behavioral, emotional, and cognitive elements (Bebell et al., 2010). This methodology will enhance the comprehension and guide the development of interventions and teaching initiatives customized to various aspects of MR.

Descriptive and inferential statistics have been widely used in MR research to analyze quantitative data. Data analysis techniques such as mean, frequency-percentage tables, t-tests, and regression are essential for understanding elements of MR research, such as impact, causality, prediction, and generalization. These statistical techniques are fundamental in building empirical foundations for hypotheses and theories in MR, emphasizing their crucial importance in quantitative research (Büyüköztürk et al., 2010). Conversely, in the design of qualitative analysis, both descriptive and content analyses have been widely utilized. As Yıldırım & Şimşek (2016) articulate, descriptive analysis organizes and evaluates data based on predefined themes, providing a systematic way to comprehend complicated data sets. Content analysis, meanwhile, aims to identify key ideas and connections within data, offering thorough explanations for the observable phenomena. Qualitative methods reveal subjective elements of MR, such as individual experiences, perceptions, and contextual factors (Yıldırım & Şimşek, 2016). The integration of quantitative and qualitative techniques in MR research enables a comprehensive understanding of the topic. Quantitative techniques establish a strong basis for measuring patterns and connections in MR, while qualitative techniques provide a nuanced comprehension of the qualitative elements. Combination of multiple methodologies is crucial for comprehensively understanding MR, including quantifiable results and individual/situational factors. In brief, the utilization of various data analysis techniques in MR studies emphasizes the intricacy of the field. The integration of quantitative and qualitative techniques enables a more nuanced exploration of the topic, advancing the field of MR and guiding future research and practical applications.

In MR research, studies have taken an extensive approach to examine various aspects, but consensus on the relationship with cognitive characteristics is lacking. The relationship between problem-solving skills and MR is complex. Several studies (Attami et al., 2020; Cahyaningsih et al., 2021; Faradillah & Fadhilah, 2021; Muntazhimah & Ulfah, 2020) have showed a positive correlation between MR and problem-solving skills. Nonetheless, the impact can vary based on the MR level of each student (Faradillah & Fadhilah, 2021; Haerani et al., 2021). Nurjannah and Jusra (2021) support this assertion, highlighting the association between increased MR and improved persistence in solving problems. These findings emphasize that understanding how MR impacts cognitive processes and problem-solving skills is necessary. Studies on the relationship between mathematical connection ability (Khairiyyah et al., 2021; Pieronkiewicz & Szczygieł, 2020; Rohmah et al., 2020a) and mathematical communication ability (Asih et al., 2021; Kurnia et al., 2018; Muntazhimah & Ulfah, 2020; Rifdah & Priatna, 2020) with MR yields inconclusive results. Chusna et al. (2023) observed that high levels of MR are linked to competence in mathematical reasoning, but additional investigation is needed to clarify these conflicting results.

The correlation between mathematical competence and MR is a multifaceted and intricate area of investigation. Recent studies (Faradillah & Humaira, 2021; Rohaeti & Koswara, 2018) have opened new avenues for understanding this relationship, challenging assumptions, and emphasizing the need for a more detailed comprehension of cognitive skills and resilience in mathematical contexts. Blended learning models have been shown (Fitri et al., 2019) to enhance MR, however, the impact on specific mathematical skills, such as spatial abilities, still requires further exploration. The effectiveness of educational techniques may fluctuate depending on various features of mathematical competence, which is important to consider when designing instructional strategies. Moreover, mathematical literacy is essential for advancing MR (Afriyanti et al., 2018), but there is a dearth of extensive studies on the interactions among students with different levels of MR during the problem-solving process. Additionally, the research conducted by Mota et al. (2016) on the modeling skills and ICT usage of pre-service teachers in mathematics education suggests that teacher preparedness and the integration of technology can significantly influence the nurturing of MR. These findings collectively indicate that the interaction between mathematical competence and MR is influenced by instruction methods, technology usage, and cognitive skills. Future research should employ various methodological approaches, such as longitudinal and mixed-methods studies, to gain deeper insights into this interaction. Effective educational strategies that enhance both mathematical skills and resilience (Cahyaningsih et al., 2021; Lee & Johnston-Wilder, 2017) can be developed through a better understanding of this correlation. Essentially, the current research landscape provides great insights but also reveals deficiencies in our comprehension of the complex correlation between mathematical competence and MR. Bridging these gaps is crucial for advancing educational practices that effectively nurture mathematical skills and resilience in learners.

Mathematical competency, including a deep grasp of mathematical concepts, precise calculations, active participation in mathematical activities, self-regulation, and the application of metacognitive strategies, is essential in education. However, the intricacies of how these facets interplay with MR are not fully elucidated. Some studies (Lee & Johnston-Wilder, 2013; Mota et al., 2016) suggest that strong mathematical competency can enhance MR. However, the relationship is not direct, as shown by Haerani et al. (2021), who discovered a connection between challenges in understanding errors and a decrease in MR. This indicates that certain aspects of mathematical competency, such as error analysis, might inversely affect MR. Adult support has a positive influence on individuals' interest in mathematics (Kahveci & Bulut-Serin, 2017; Khairiyyah et al., 2021), which could potentially improve MR. This implies that the educational environment and support systems play a crucial role in fostering MR. However, challenges in mathematical estimation and operations (Chusna et al., 2023) can could impede the development of MR. Additionally, the current positive correlation between self-regulation, metacognitive strategies, and academic performance (Lyakhova & Joubert, 2022; Trigueros et al., 2020) prompts inquiries regarding their direct influence on MR. Although the positive impact of these factors on academic achievement is recognized, their precise role in promoting MR, particularly in mathematics, requires additional research. In conclusion, understanding how different elements of mathematical competency interact with MR is vital. Future studies should focus on analyzing these intricacies, potentially using longitudinal studies (Burris et al., 2006; Sammons et al., 2007) or experimental designs (Santagata et al., 2010), to develop effective instructional practices (Agustin et al., 2022).

The significance of affective features in MR is progressively acknowledged as a pivotal for academic achievement and psychology. Trigueros et al. (2020) found a negative link between MR and anxiety, indicating that high anxiety levels may hinder MR progress. This finding holds great importance, especially in light of Cropp's (2017) study that showed the efficacy of peer interventions in diminishing anxiety levels, thereby potentially enhance MR. Johnston-Wilder et al. (2021) connect self-determination theory to MR promotion, highlighting the need for a supportive and independent atmosphere for students. This aligns with the positive correlations found between motivation, metacognitive strategies, and MR in several studies (Afriyanti et al., 2018; Joy & Obiagaeri, 2019; Trigueros et al., 2020). Nevertheless, Faradillah & Wulandari (2021a) posits that this correlation may not follow a linear pattern, depending on individual differences or contextual factors. Further, perception, attitude, and belief are influential in MR development (Atahan & Akyüz, 2020; Bell & Kolitch, 2000; Duggan et al., 2017; Layco, 2020), but more investigation is needed to understand these interactions. Respect, emotional intelligence, empathy, well-being, and emotional responses also impact MR (Baker et al., 2019; Faradillah & Wulandari, 2021b; Joy & Obiagaeri, 2019; Kahveci & Bulut-Serin, 2017; Layco, 2020; Mota et al., 2016). Additionally, the value mathematics itself is linked to positive outcomes in MR (Atahan & Akyüz, 2020; Duggan et al., 2017; Lyakhova & Joubert, 2022; Mota et al., 2016). Understanding students' perception of mathematics can improve MR. The influence of affective features on MR requires further investigation. Future research should concentrate on clarifying the intricate dynamics of these relationships to enhance MR in educational environments (Gómez-Chacón, 2017).

The impact of pedagogical factors on students' MR is significant, as evidenced by numerous studies (Asih et al., 2021; Atahan & Akyüz, 2020; Muntazhimah & Ulfah, 2020; Layco, 2020; Lee & Ward-Penny, 2022). These studies indicate that diverse teaching approaches, instructional interventions, and teacher qualities positively affect MR. These results emphasize the critical role of pedagogy in shaping students' resilience in mathematics. However, the causal direction of these effects is sometimes uncertain. Several studies (Asih et al., 2021; Khairiyyah et al., 2021; Rohmah et al., 2020a) have found that certain educational models may not consistently yield positive outcomes in the context of MR. This implies that the efficacy of pedagogical strategies might be influenced by the circumstances or underlying variables (Buckley & Sullivan, 2023; Tambunan, 2021). Further, specific teaching methods have been found to improve both MR and overall learning (Cropp, 2017; Johnston-Wilder et al., 2021; Kahveci & Bulut-Serin, 2017; Lee & Johnston-Wilder, 2013). Nevertheless, there is a noticeable dearth of comprehensive results on the overall effectiveness of educational settings and course designs (Lee & Ward-Penny, 2022; Pieronkiewicz & Szczygieł, 2020). It is necessary to conduct a more comprehensive study on the effects of educational settings and curricula on MR. The role of teachers in this process is important. Teachers' use of tools and capabilities can enhance MR, but further investigation is needed on factors such as effective course structures and the optimal utilization of teaching environments (Layco, 2020; Lee & Ward-Penny, 2022; Pieronkiewicz & Szczygieł, 2020). In conclusion, more investigation is needed to understand the impact of pedagogical factors, such as different pedagogical approaches, teacher competencies, and educational environments, on MR. Future research should prioritize understanding these relationships to improve teaching strategies for fostering MR.

The current research highlights that demographic characteristics and students' MR and attitudes towards mathematics are interconnected. Previous studies (Bell & Kolitch, 2000; Duggan et al., 2017) have laid the groundwork for understanding how demographic factors intersect with MR. Recent research (Faradillah & Fadhilah, 2021; Faradillah & Wulandari, 2021b; Lyakhova & Joubert, 2022) has also demonstrated significant influences of institutional differences, interdisciplinary variations, learning rates, and individual characteristics on students' attitudes towards mathematics. These findings are crucial for understanding MR in in different educational and demographic contexts. This understanding emphasizes the role of external and personal elements in shaping students' resilience in mathematics. The insights gained from these studies are important for educational practitioners and institutions. They emphasize the necessity for individualized educational strategies that consider the different backgrounds and learning environments. By recognizing and addressing these varying influences, educators can cultivate inclusive, effective, and context-specific approaches to foster MR. This approach contributes to the broader discourse on MR and learning strategies in mathematics education. The impact of demographic characteristics on MR underscores the need for a multi-dimensional approach to educational practices. Further research should investigate how specific demographic factors influence MR development and how educational practices can support diverse student populations (Hernandez-Martinez & Williams, 2013). In conclusion, examining the relationship between demographic characteristics and MR is crucial for educators and researchers. Understanding and addressing these interactions can improve educational strategies and mathematical learning outcomes.

Social factors such as family, peers, teachers, counselors, and learning environments significantly affect MR. Goodall & Johnston-Wilder (2015) stress the positive role of family and caregivers in enhancing MR, suggesting that a supportive home environment is important for developing resilience in mathematics. This suggests that a supportive home environment plays a crucial role in students' resilience in mathematics. Conversely, peer interactions can have a negative impact on MR according to Muntazhimah & Ulfah (2020), indicating the need for social skill development to mitigate these effects. Moreover, the home environment, including parent relationships and collaborative efforts, is key in shaping MR (Layco, 2020). However, the home-school relationship seems to have minimal influence, suggesting that the educational setting may have a more immediate impact on MR development. Understanding social relationships in educational contexts is critically important. Context-sensitive approaches in schools and learning environments are needed to effectively enhance MR. This includes acknowledging the role of family and caregivers, understanding peer dynamics, and considering the broader social environment. Further research should explore how different relationships and interactions within the educational ecosystem influence MR. In practice, educational strategies that consider social dynamics can enhance MR. This could involve interventions aimed at improving peer interactions, engaging families more deeply in the educational process, and creating a more supportive overall learning environment. The interplay of social factors underscores the need for a holistic approach in research and educational practice. Understanding and addressing these influences can help educators support students in developing resilience in mathematics.

The research findings highlight the critical role of different stakeholders, particularly teachers, in promoting MR. Studies by various researchers (Baker et al., 2019; Muntazhimah & Ulfah, 2020; Neumann et al., 2021) emphasize the importance of targeted recommendations for teachers in enhancing MR in educational settings. These recommendations stress the need for teachers to be aware of the affective, cognitive, and pedagogical aspects of MR (Atahan & Akyüz, 2020; Johnston-Wilder et al., 2021). Diverse research methodologies and comprehensive samples are suggested by researchers (Cropp, 2017; Duggan et al., 2017; Faradillah & Wulandari, 2021b; Haerani et al., 2021; Kahveci & Bulut-Serin, 2017; Lee & Johnston-Wilder, 2013; Lyakhova & Joubert, 2022; Mota et al., 2016) to understand MR in different contexts. Longitudinal research and single-subject experimental designs are also recognized for their significance in understanding MR across diverse populations (Cropp, 2017; Layco, 2020). Moreover, the impact of MR on learning and emotional intelligence (Faradillah & Wulandari (2021a) indicates the need for student-centered recommendations. Blended learning models are discussed as beneficial but also present challenges in fostering MR (Khairiyyah et al., 2021). This reflects the evolving nature of educational practices and their impact on MR. Recommendations for school administrators, psychological counselors (Goodall & Johnston-Wilder, 2015; Joy & Obiagaeri, 2019), and parents (Layco, 2020; Pieronkiewicz & Szczygieł, 2020) are emphasized in supporting children's mathematical activities and thereby MR development. Raising MR awareness from an early age (Atahan & Akyüz, 2020) and comprehensive societal approach are advocated. These findings suggest the need for a comprehensive approach to MR, including collaboration across all educational stakeholders to create effective methods that meet the varied needs of children. Overall, enhancing MR requires the involvement of various stakeholders and more research is needed to fully understand its associations with other abilities and processes.

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Note: (* marked references are the studies included in the review)

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